STRUCTURAL DESIGN – I

04. PROPERTIES OF CONCRETE & STEEL

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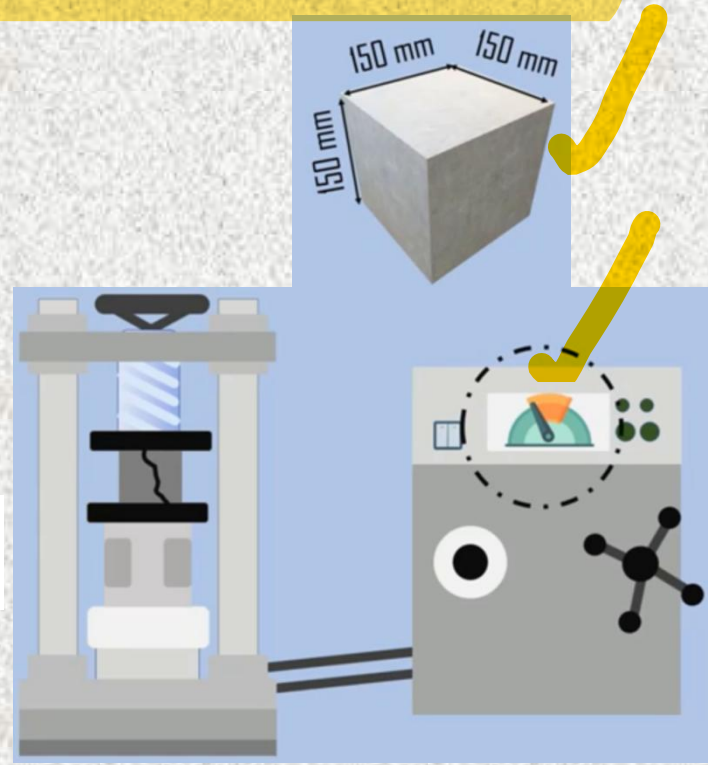
BEHAVIOUR OF CONCRETE UNDER UNIAXIAL COMPRESSION

Compressive Strength of Concrete

- Strength of concrete under uniaxial compression is determined
- Standard cube specimens (150 mm size) are generally tested 28 days after casting (and continuous curing).
- They are loaded to failure in a Compression Testing Machine @ uniform strain-rate of 0.001 mm/mm per minute , as per IS 516 : 1959.

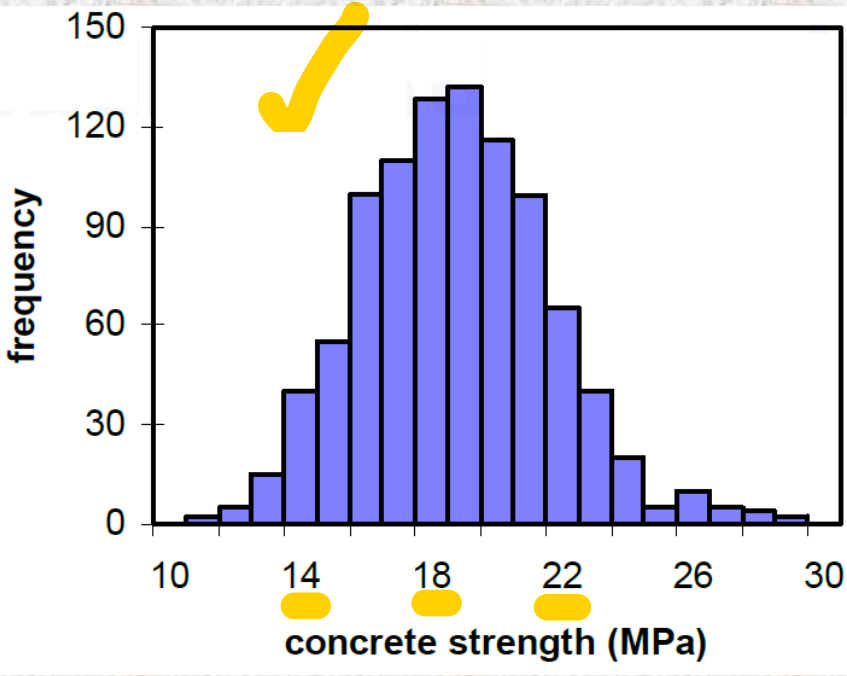
- Compressive strength = $\frac{\text{Failure Load}}{\text{Cross-sectional Area of specimen}}$

(expressed in N/mm^2 or MPa)



CHARACTERISTIC COMPRESSIVE STRENGTH

- Concrete is a material whose compressive strength has considerable *variability*.
- Cube specimens that are taken from the same mix give different values of compressive strength in laboratory tests. This may be due to the non-homogeneous nature of concrete.
- Experimental studies reveal that the frequency distribution of compressive strength of concrete (**for a given mix**, as determined by compression tests on a large number of specimens) is approximately **Gaussian Curve** or **Normal Curve**, as shown.



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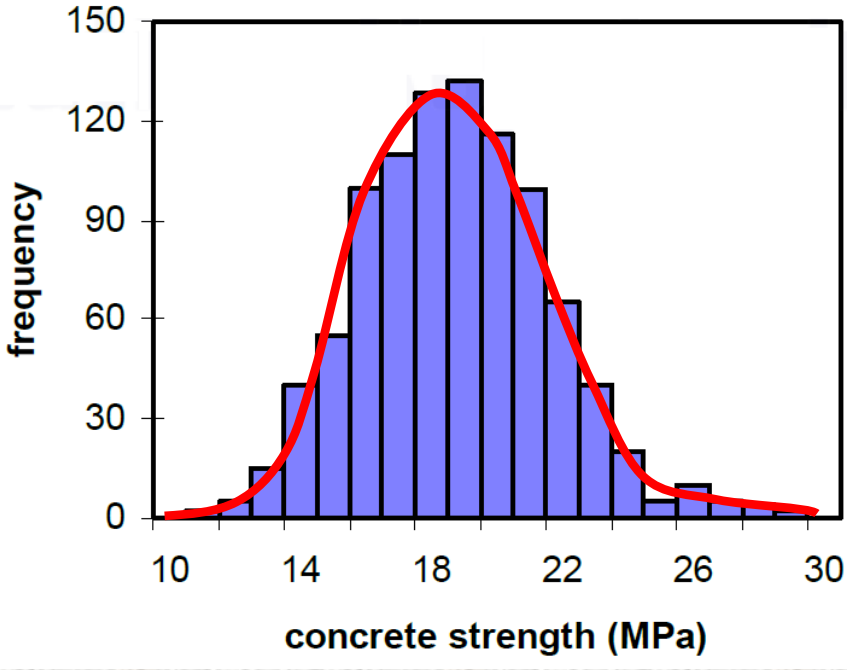


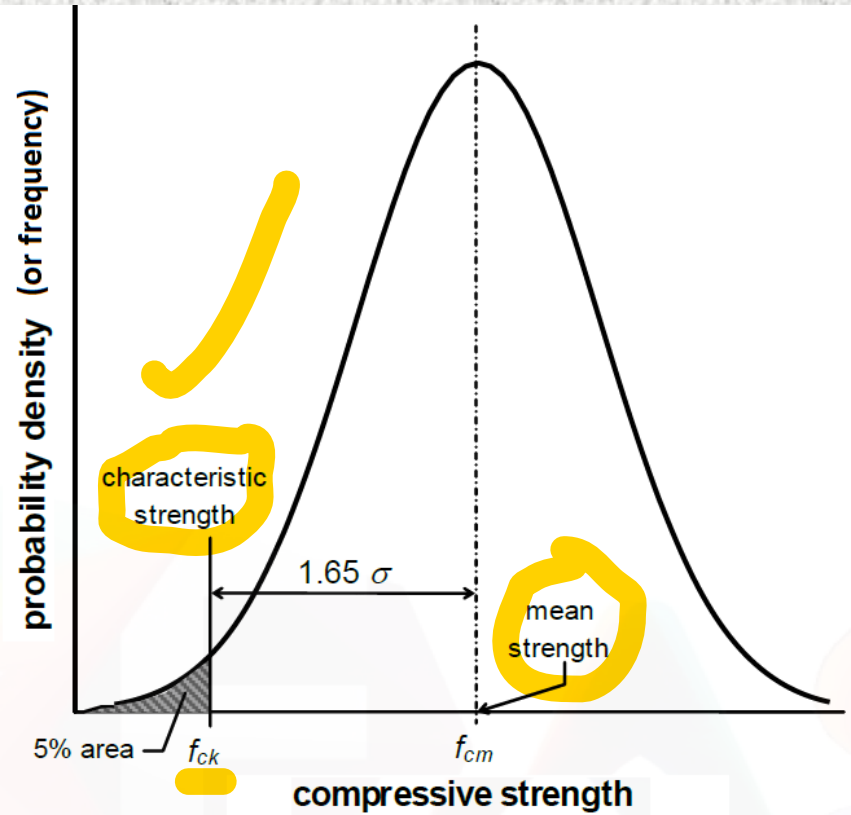
- Inorder to finalize a strength value for a definite concrete mix, the Code has defined *characteristic strength of material* (concrete or steel).

- As per IS456, ***Characteristic Strength*** is the strength of the material below which not more than 5% of the test results are expected to fall. (see figure)
- This assures that the concrete mix is of a certain minimum strength.

- From this, the mean strength of the concrete mix f_{cm} (as obtained from 28-day compression tests) shall be significantly greater than the characteristic strength f_{ck} that is specified by the designer. That is,

$$f_{cm} = f_{ck} + 1.65\sigma$$

where the standard deviation σ depends on quality control.



GRADE OF CONCRETE

- The ***quality*** or ***grade*** of concrete is designated in terms of letter ‘M’ followed by a number. ‘M’ refers to mix; the number represents the ***28-day characteristic compressive strength of concrete cubes (150mm)*** expressed in ***MPa***.

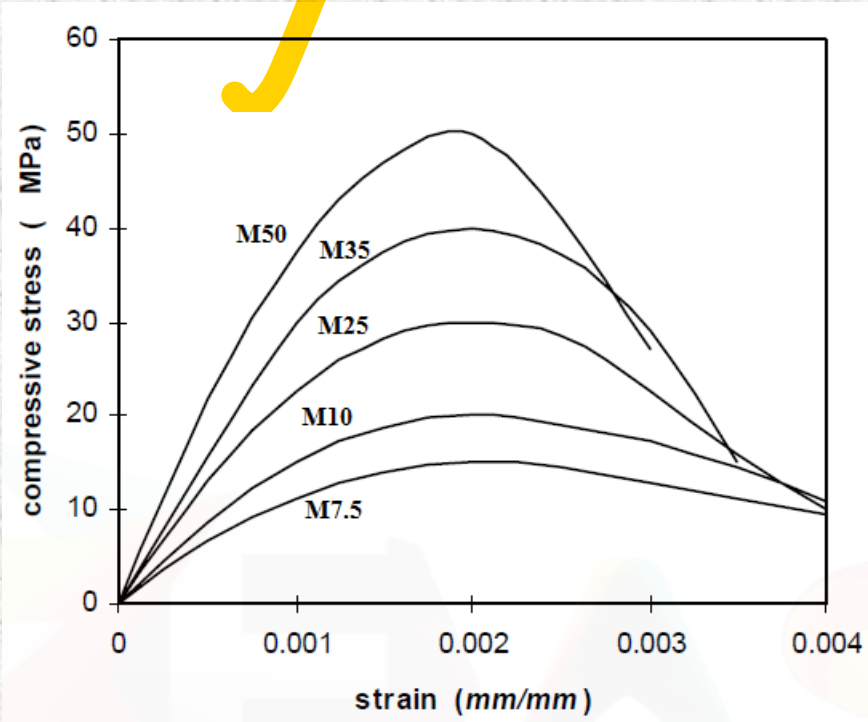
  Eg: M20 denotes the concrete mix with 28-day characteristic cube compressive strength of 20MPa.

- Minimum grade of concrete used is dictated by durability (the environment to which the structure is exposed to, expressed in terms of exposure conditions), as given below.

Exposure Condition	Minimum grade of concrete for RCC works
Mild	M20
Moderate	M25
Severe	M30
Very severe	M35
Extreme	M40

- Classification
  - Ordinary concrete – M10 to M20
  - Standard concrete – M25 to M55
  - High Strength concrete – M60 and above

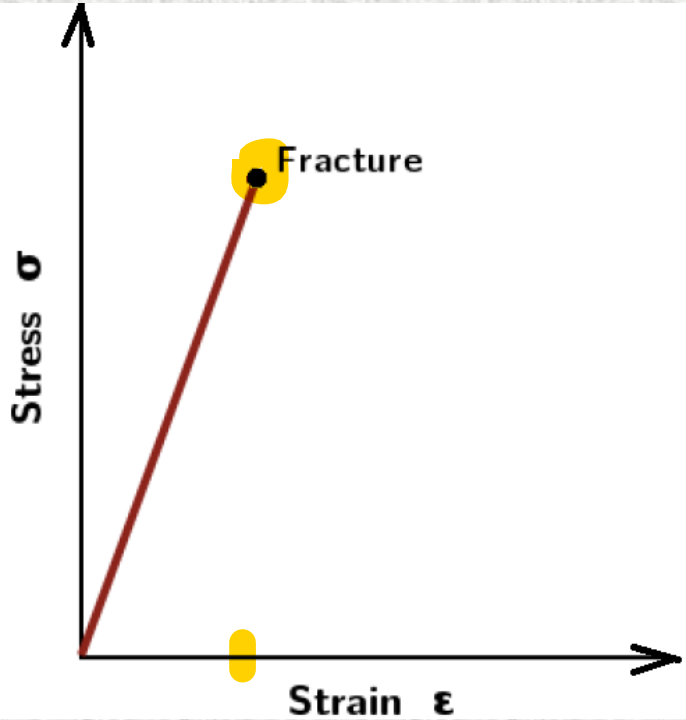
- Stress-Strain curves of concrete for various grades obtained from uniaxial compression tests are shown in figure
- The curves are linear within the initial portion of the curve. This is approximately true upto one-third of the maximum stress level, beyond which the non-linearity continues
- For higher grades of concrete, the initial portion of the stress-strain curve is steeper, but the failure strain is low. For low strength concrete, the initial slope of curve is gentle but has high failure strain. (observe the figure)



BEHAVIOUR OF CONCRETE IN TENSION

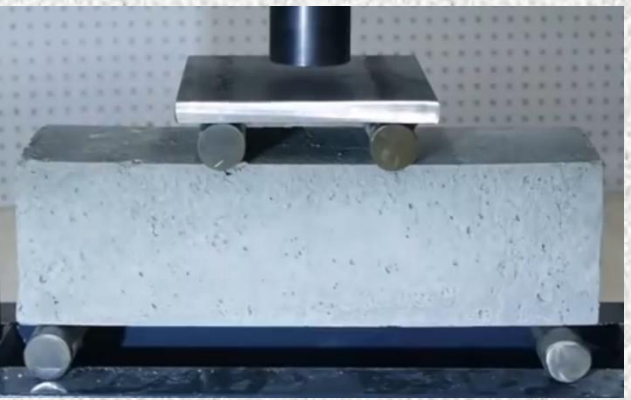
- Generally, ***concrete is very weak in tension***. Tensile strength of concrete is only about ***7 to 15 % of the compressive strength***. Since the tensile strength of concrete is very low, it is often ignored in design.

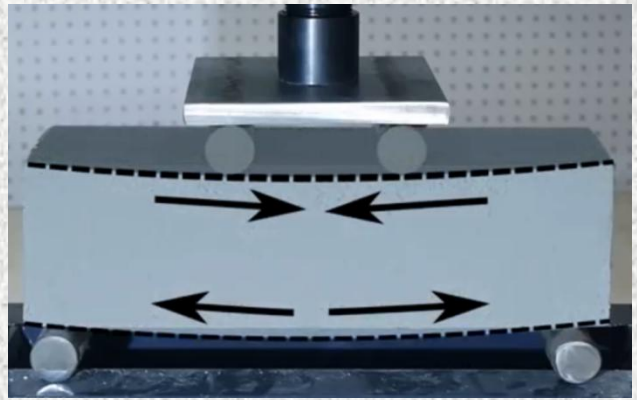
- Failure strain of concrete in tension is very low. It is found to be in the range of 0.0001 to 0.0002. Hence, the stress-strain curve of concrete in tension is generally approximated as a straight line from the origin to the failure point.

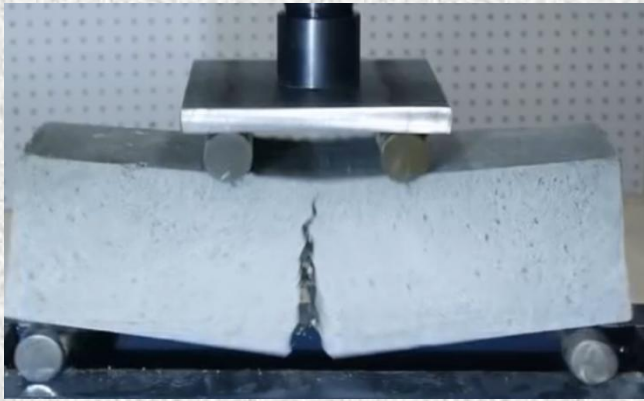


BEHAVIOUR OF CONCRETE IN FLEXURE

- Flexural members, such as beams and slabs, develop both tensile stress and compressive stress in the cross section, on either sides of the neutral axis.

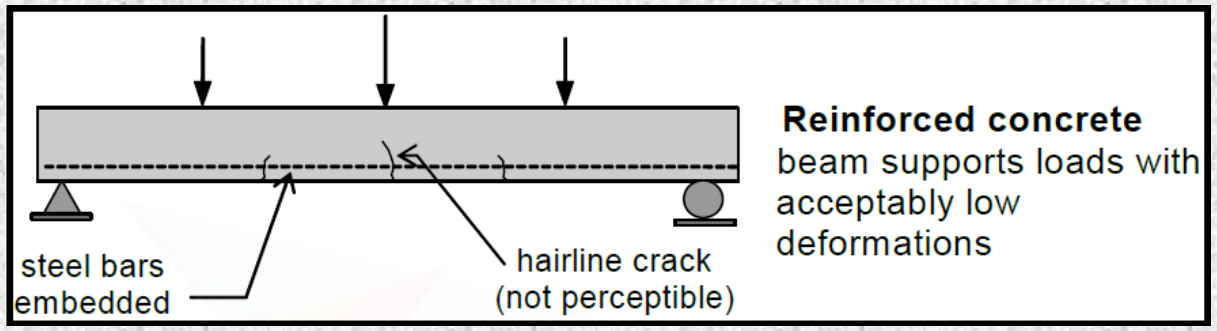




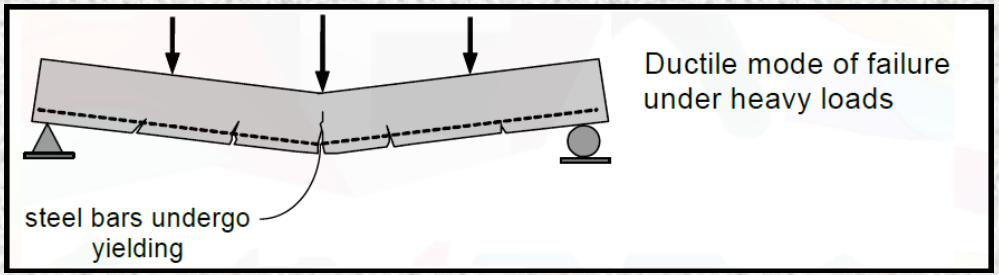


- Plain concrete is ineffective, where tensile stresses develop, and cracking of concrete occurs in the tension zone.

- Hence, ***steel bars (steel reinforcements)*** are embedded in the tension zone of the concrete to compensate for the concrete's incapacity to resist tension.



- Reinforcing steel imparts ***ductility*** to the structural member. As a result, if a properly reinforced beam were to fail in tension, then such a failure would, fortunately, be preceded by large deflections caused by the yielding of steel, thereby giving ample warning to the user about the impending collapse.



REINFORCING STEEL (or Rebars)

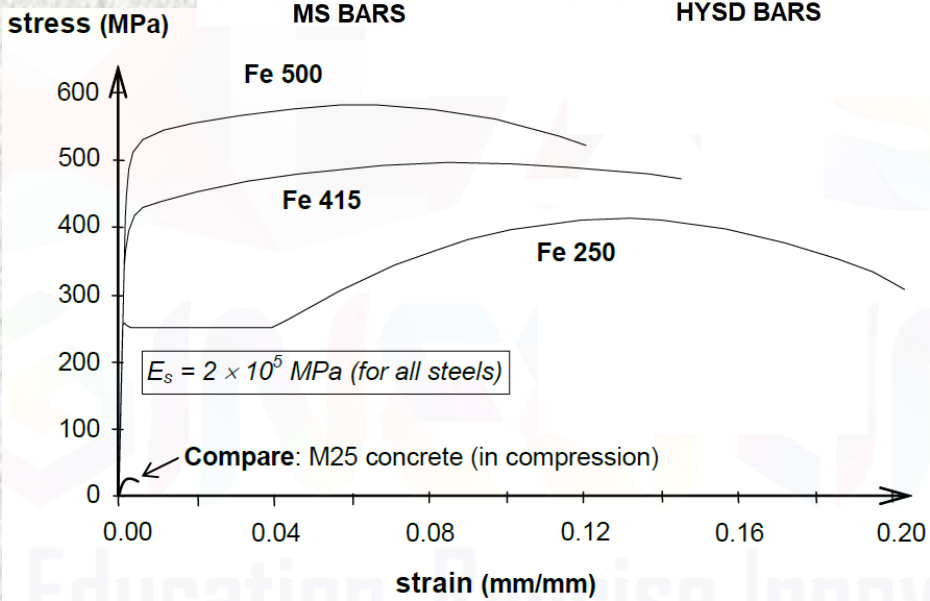
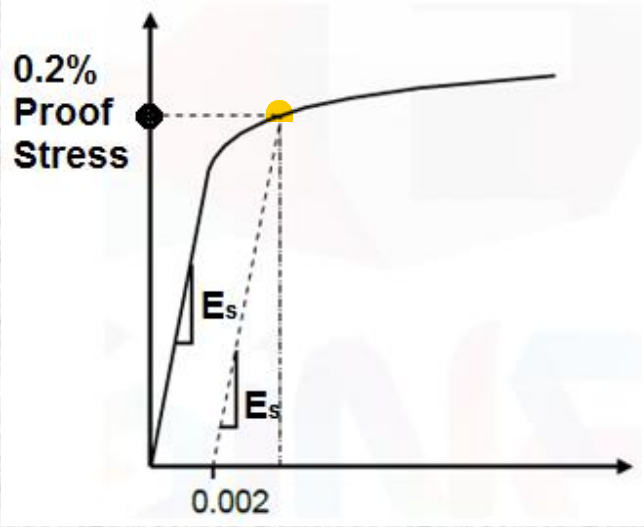
MS BARS

HYSD BARS

Reinforcing steel may be categorized broadly into:

- **Plain Mild steel bars (MS bars)**
  - has well-defined yield point
  - Eg: *Fe250* – Yield strength= 250MPa; Ultimate strength= 412MPa; Min % elongation= 22%

- **High Yield Strength Deformed bars (HYSD bars)**
  - doesnot have well-defined yield point
  - these are cold-worked bars (involves stretching and twisting of mild steel bars)
  - Eg: *Fe415* – Yield strength= 415MPa; Ultimate strength= 485MPa; Min % elongation= 14.5%
  - Eg: *Fe500* – Yield strength= 500MPa; Ultimate strength= 545MPa; Min % elongation= 12%



- Characteristic strength of reinforcing steel =
  - yield strength of steel– for those with well-defined yield point (Fe250)
  - 0.20% Proof Stress – for those without well-defined yield point (Fe415&Fe500)
- 0.2% Proof Stress is measured as shown below